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WASHINGTON STATE UNIVERSITY
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# ESRP 531
# Fundamentals of Environmental Toxicology

Lecture 3

Nature of Toxicity:

Measurement, Expression, Quantification, Influential Factors

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## Toxicity: Critical Variables

- Two variables are most important in determining the likelihood that exposure to a toxicant wil result in an adverse response:
  - Amount of exposure (dose)
    - Should be distinguished from dosage, the amount relative to body weight, and absorbed dose (the amount actually in the body)
  - Frequency and duration of exposure (time)

## Another Definition of Toxicity

- "The accumulation of injury over short or long periods of times that renders an organism incapable of functioning within the limits of adaptation or other forms of recovery." (Rozman et al. 2001)
- This definition is organism centric, but environmental toxicology is necessarily focused on higher levels of organization
  - A lofty goal: protect the ecosystem

## Policy Goal: No loss of fisheries from use of aquatic herbicide

| Assessment Endpoints | Indicators of Effects | Measurement Endpoints |
|---|---|---|
| Probability of >10% reduction in game fish production | Lab toxicity to fish | Fathead minnow LC50; larval bass concentration/mortality function |
| | Lab toxicity to food-chain organisms | Daphnia LC50; Algal EC10 |
| | Field toxicity to fish | Caged fish bioassay (% mortality) |
| | Population abundance in treated lake | Catch per unit effort; size/age ratios by age classes |

## Policy Goal: No unacceptable reductions in avian population

| Assessment Endpoints | Indicators of Effects | Measurement Endpoints |
|---|---|---|
| Proportion of raptors killed within the region of use | Lab toxicity to prey | Rat LD50; Quail dietary LC50 |
| | Lab toxicity to raptors | Sparrow hawk dietary concentration/response function |
| | Avian field toxicity | Number of prey carcasses per hectare; Number of dead or moribund raptors per ha |

## Policy Goal: No unacceptable reductions in avian population (cont'd.)

| Assessment Endpoints | Indicators of Effects | Measurement Endpoints |
|---|---|---|
| Increase in rates of decline of declining bird populations in the region of use | Lab toxicity to birds | Quail dietary LC50; Starling dietary LC50 |
| | Avian field toxicity | Number of bird carcasses per hectare by species |
| | Trends in population of declining birds | Rates of decline in areasof use as proportion of reference areas |

## Endpoints

- We are still stuck with measuring effects on individuals, even when we want to protect whole communities or ecosystems
- Must have endpoints if we are to measure toxicity at the individual level
  - An endpoint is the direct or indirect biochemical, cellular, physiological, or behavioral response following an exposure to a toxicant

## Lethality Endpoint

- In the previous tables of policy goals and measurement endpoints, lethality as represented by the LD50 or LC50 was the most important endpoint on the individual level
  - LD50: dose lethal to 50% of the test population
  - LC50: concentration lethal to 50% of the test population

## Other "Lower Level" Endpoints

- Biochemical
- Genetic
- Cellular
- Physiological
- Morphological
- Functional
- Behavioral

## Testing Organisms ("The Guinea Pigs")

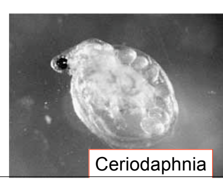
- Mammalian toxicology for risk assessment
  - Rodents
  - Dogs
- Ecological toxicity testing for RA
  - Invertebrates, vertebrates, microbes, plants
  - Aquatic, terrestrial

## Ecotox Testing: Aquatic Invertebrates

- *Daphnia magna* and other species
- Amphipod (scuds)
- Insects
  - Stoneflies
  - Mayflies
  - Midges


Daphnia


Amphipod


Ceriodaphnia

## Ecotox Testing: Aquatic Vertebrates


Coho salmon


Atlantic salmon


Fathead minnow


Bluegill sunfish


Rainbow trout

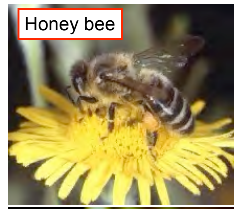
## Ecotox Testing:  Aquatic Plants


Green algae

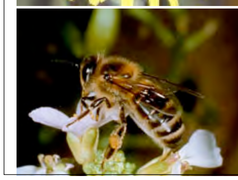

Duckweed


Parrotfeather

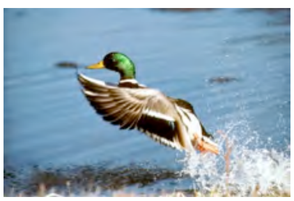
## Ecotox Testing:  Terrestrial Invertebrates

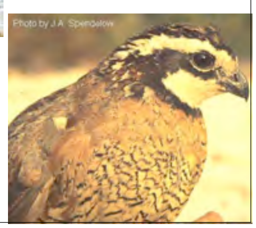

Honey bee


Monarch butterfly



## Ecotox Testing:  Terrestrial Vertebrates


Mallard Duck

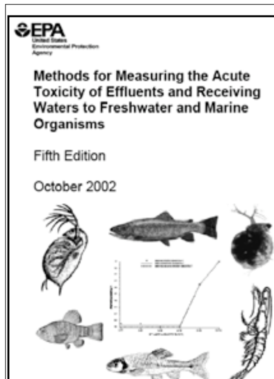


Northern Bobwhite Quail

## Ecotox Testing:  Terrestrial Vertebrates


Rat

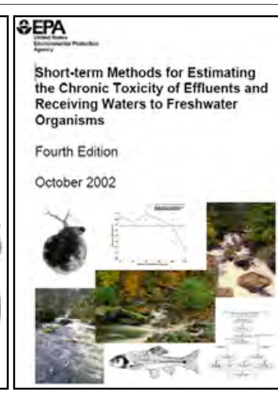
## Ecotox Testing:  Terrestrial Plants


EPA

Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms

Fifth Edition

October 2002


EPA

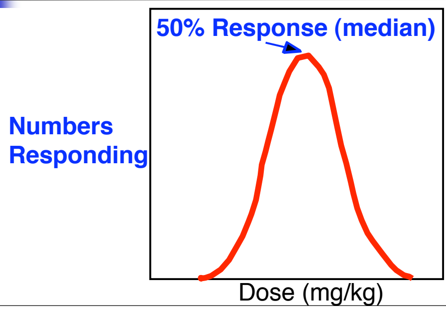
Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms

Fourth Edition

October 2002

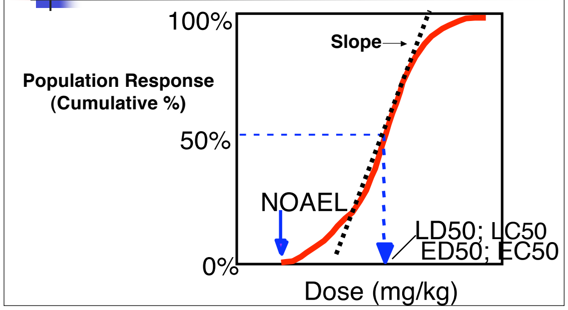
Basis for Quantitatively Expressing Toxicity

## Distribution of Individual Responses to Increasing Doses




Basis for Quantitatively Expressing Toxicity

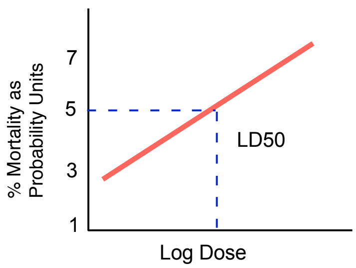
## Cumulative Proportion Responding




Basis for Quantitatively Expressing Toxicity

## Probit Transformation-Linearization of the Dose-Response Curve

| % Mortality | Probit |
|---|---|
| 10 | 3.72 |
| 20 | 4.16 |
| 30 | 4.48 |
| 40 | 4.75 |
| 50 | 5.00 |
| 60 | 5.25 |
| 70 | 5.52 |
| 80 | 5.84 |
| 90 | 6.28 |




## Utility of the LD50

- Only meaningful in context of a comparison
  - Relative hazard of two or more chemicals
  - Relative susceptibility of two or more species or two or more populations of the same species
  - Absolute hazard of a single chemical when oral and dermal routes of exposure are compared
  - Comparative assessment endpoint to examine how other variables affect toxicity

## Threshold

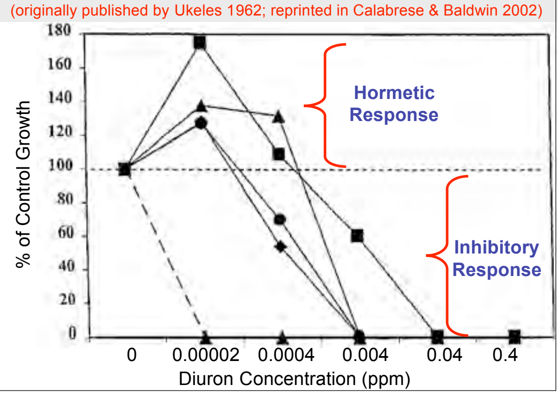
- Expressed as the NOAEL or NOAEC
  - No Observable Adverse Effect Level
  - No Observable Adverse Effect Concentration
- In EPA risk assessments, empirically derived, although can be modeled based on curve fit function
- In rodent tests, based on chronic and subchronic exposure tests
- In ecotox tests, based on chronic exposure; i.e., life cycle tests

## Hormesis

- “Low dose stimulation, high dose inhibition”
- Recent analysis of many studies shows it is a common phenomenon across species and compounds

Response of Five Algal Species to the Herbicide Diuron

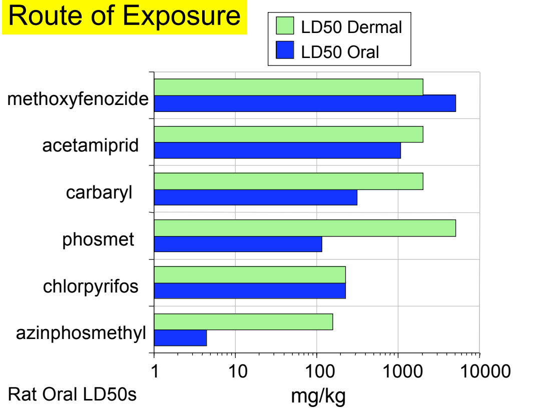
(originally published by Ukeles 1962; reprinted in Calabrese & Baldwin 2002)



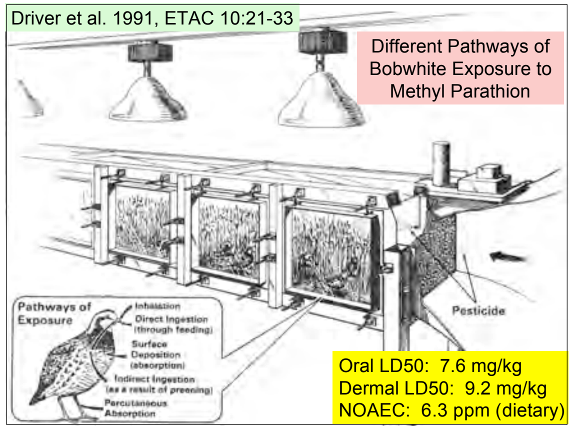

## Factors Influencing Toxicity

- Factors related to toxic agent
- Factors related to exposure situation
- Factors related to the exposed organism
- Environmental factors related to the subject

## Route of Exposure

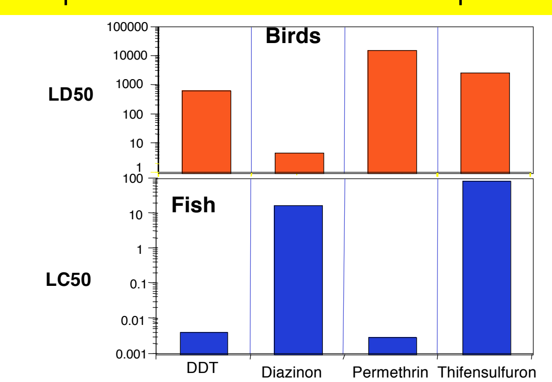


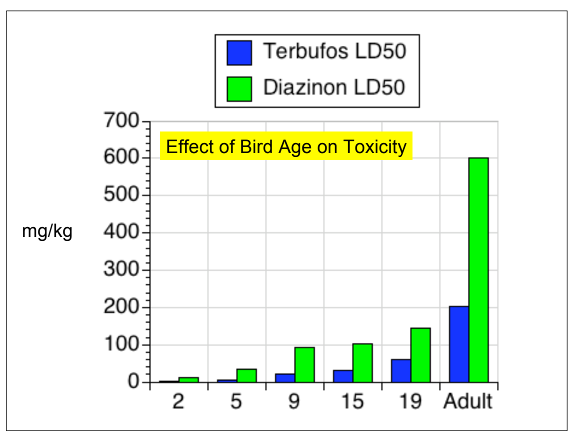

Driver et al. 1991, ETAC 10:21-33




Oral LD50: 7.6 mg/kg
Dermal LD50: 9.2 mg/kg
NOAEC: 6.3 ppm (dietary)

## Comparison of Hazard to Different Species



Effect of Temperature & Infection
Chronic Toxicity of Pentachlorophenol to Clams
(Heinonen et al. 2001, ETAC 20(12):2778-84

| Temperature | Exposure (µg/L) | Infection Status | Mean Survival Time (hours) |
|---|---|---|---|
| 5 ºC | 100 | Infected | 611 |
| 5 ºC | 100 | Uninfected | 574 |
| 5 ºC | 300 | Infected | 525 |
| 5 ºC | 300 | Uninfected | 506 |
| 19 ºC | 100 | Infected | 136 |
| 19 ºC | 100 | Uninfected | 60 |
| 19 ºC | 300 | Infected | 63 |
| 19 ºC | 300 | Uninfected | 33 |

# Inverse Temperature Effects

- Generally, the higher the temperature, the greater the toxicity at a given concentration
- However, DDT and pyrethroid insecticides are exceptions
  - Toxicity decreases with increased temperature and increases with decreased temperature